Reduced Tillage - Energy Systems for Furrow Irrigated Sorghum on Wide Beds

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ABSTRACT

LIMITED tillage and no-till management of continuous irrigated sorghum was evaluated on wide beds separated by 1.5-m spaced water furrows in the Southern Great Plains. No-till beds, no-till beds with furrows ripped, sweep-undercut, and conventional chisel-disk tillage were compared.

Glyphosate, a systemic herbicide applied before planting, successfully controlled volunteer sorghum on no-till bed treatments. A double-disk opener planter with coulters and a staggered double-disk opener planter successfully operated through plant residues in 0.75-m spaced rows on the wide beds and penetrated the relatively hard soil surface to open a seed slot on the no-till bed treatments.

Conventionally tilled sorghum averaged 5% less grain yield and 14% less water use efficiency than did other treatments. Fuel energy and time requirements were reduced with limited and no-tillage, however no-till costs were higher than with conventional or limited tillage. The limited (sweep) tillage treatment had the lowest labor and fuel energy cost; being $12.00, $17.00, and $8.50/ha less than no-till beds, no-till beds furrow ripped, and conventional tillage, respectively.

INTRODUCTION

Feed grains are grown annually on about 1.1 million ha (2.8 million acres) of irrigated land in the Southern High Plains. This area has been approximately evenly divided between annually cropped corn and grain sorghum.

Rapidly increasing energy costs for irrigation water pumping have increased producer interest in shifting from corn to grain sorghum. Because of drought tolerance and a shorter growing season, grain sorghum is produced with less irrigation water than is required for corn. The predominate irrigation method is by gravity flow through graded furrows.

Irrigation water is supplied by deep wells extending into the Ogallala Aquifer. Pumping lifts range mostly from 60 to 120 m, with pumping energy requirements varying accordingly from 0.093 L/m^3 (2.53 gal/ac-in.) to 0.186 L/m^3 (5.06 gal/ac-in.) of diesel equivalent, assuming a 75% pump efficiency. In addition to higher pumping energy costs, the low annual precipitation about 500 mm (20 in.) and the declining groundwater supply available for irrigation, emphasize the need for the most efficient use of water for crop production. At the same time, concern over the cost of fuel, labor, and machinery for crop production has spurred an interest in reduced tillage systems.

Previous research at Bushland, TX, indicated that tillage can be reduced for annual cropping of irrigated sorghum without significantly reducing yields. There were, however, some problems with controlling volunteer sorghum that emerges shortly before June 1 planting time. With no-till systems, herbicides that were available in the early 1970's were not satisfactory for controlling the volunteer sorghum (Allen et al., 1975). With a limited tillage mulched-bed system where the beds were undercut with a rod weeder to kill volunteer, the resulting loose seed bed and uprooted stalks caused planter plugging when seeding two closely spaced rows (0.25 m) per bed (Allen et al., 1980). The elevated and rounded beds were separated by 1.0-m spaced water furrows.

This study was conducted to evaluate the effects of limited tillage and no-tillage system treatment effects on volunteer sorghum control, stand establishment, crop yield, water use efficiency, and energy use where grain sorghum was grown in wider spaced rows (0.75 m) on wide flat beds separated by 1.5-m spaced water furrows (Fig. 1). Wide beds with 1.5-m spaced furrows were successfully managed previously at Bushland by Allen and Musick (1972) with wheat grown on newly formed flat beds followed by no-till double-cropped grain sorghum. Wheel traffic was confined to the centers of the wide beds to avoid traffic in water furrows (Johnston and Van Doren, 1967). Musick and Dusek (1974) found that soil water intake was adequate for sorghum with water furrows spaced up to 1.5 m apart on a Pullman clay loam. Stone et al. (1979 and 1982) successfully grew grain sorghum on wide beds with 1.4-m spaced irrigation furrows on a Richfield clay loam at Goodwell, OK, on the Southern High Plains.

PROCEDURE

The study was established on existing wide flat beds after harvesting a 1980 grain sorghum crop. The soil, a fine-textured, slowly permeable Pullman clay loam

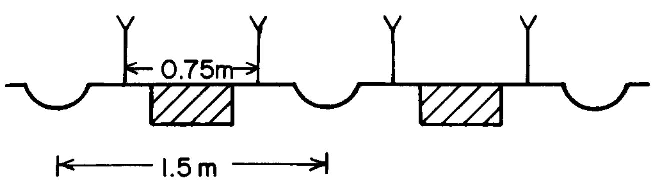

Fig. 1—Bed furrow configuration showing location of sorghum rows. Wheel traffic zones are cross hatched.

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(Torrertic Paleustoll) occupies about 1.2 million ha of irrigated land in the Southern High Plains and was described by Unger and Pringle (1981). The soil has a silty clay loam Ap horizon (0-15 cm), a dense clay B21t horizon (15-40 cm), and a silty clay B22t horizon (40-70 cm). The experiment had a randomized block design of four tillage treatments with two replications. Treatment strips were 9 m wide by 400 m long on a 0.15% slope. Data sampling locations were at 60, 200, and 335 m from the upper end of each strip. The residue levels reported for different treatments and times were visually estimated as percent soil cover.

Four tillage treatments provided a range in tillage intensity and residue management. Tillage treatments were sweep undercutting (T-1), no-till beds with furrows ripped (T-2), no-till beds (T-3), and conventional disking and chiseling (T-4). The tillage and preplant irrigation sequences are listed in Table 1.

Although T-2 and T-3 are described as no-till bed treatments, the winter application of anhydrous ammonia (NH_3) at 150 kg N/ha with narrow knives, opened a slot about 2 cm wide and 12-15 cm deep in the center of the wide beds. The NH_3 knives, spaced 0.75 m apart, also cut a slot in the furrows. Treatments T-2 and T-3 also required water furrow reopening before the preplant irrigation. Relatively narrow furrows, about 0.30 m wide, were formed by tool bar-mounted narrow shovel points with adjustable wings (Fig. 2). Furrows on T-1 and T-4 were also formed with the machine. The furrow openers were adjusted to avoid leaving a ridge of clods along furrow edges and in the path of plant rows.

Tractor wheel traffic during tillage, spraying, and seeding was confined to the center of the beds between the crop rows as illustrated in Fig. 1. Propazine [2-chloro-4,6-bis (isopropylamino)-s-triazine] was applied in April at 3.3 kg/ha for preplant and seasonal weed control.

After the preplant irrigation and just before seeding, the relatively new systemic herbicide, glyphosate [N-(phosphonomethyl) glycine] was applied at 0.28 kg/ha on T-2 and T-3 for volunteer sorghum control. At the same time, a shallow (sweep cultivation-furrow cleanout) operation was performed on T-1, and a rolling

TABLE 1. TILLAGE AND PREPLANT IRRIGATION SEQUENCES USED IN FOUR TREATMENTS AT BUSHLAND, TEXAS

Treatment	Operation	
	Fall-winter	Spring
T-1 (sweep-undercut)	Shred stalks Apply NH_3 Sweep 15-18 cm deep	Open furrows Apply propazine Pre-irrigate Sweep 7-10 cm deep and reopen furrow Plant
T-2 (no-till beds, furrow-rip)	Shred stalks Apply NH_3 Rip furrows	Reopen furrows Apply propazine Pre-irrigate Apply glyphosate Plant
T-3 (no-till beds)	Shred stalks Apply NH_3	Reopen furrows Apply propazine Pre-irrigate Apply glyphosate Plant
T-4 (conventional)	Shred stalks Apply NH_3 Disk Chisel 15-18 cm deep	Disk Open furrows Apply propazine Pre-irrigate Rolling cultivator Plant

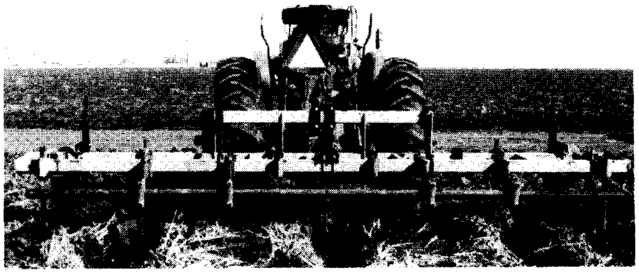

Fig. 2—Furrow openers with adjustable wings mounted on toolbar operating in sweep-undercut treatment.

cultivator was used on T-4 to control volunteer sorghum emerging after the irrigation.

Sorghum was seeded in two 0.75-m spaced rows on the flat beds (Figs. 1 and 3). A John Deere* 7100 Max-Emerge planter with double disk openers and rolling coulters was used in 1981 and 1982. In 1983, an International Harvester (IHC) 800 Early Riser planter with staggered double disk openers was used.

In 1981, plots were preplant irrigated on May 20 and sorghum was planted on June 8. Hot dry winds caused poor seedling emergence and replanting was required in late June. In 1982, the plots were preplant irrigated on May 13 and sorghum as planted on June 1. In 1983, the sorghum was planted on June 15 without a preplant irrigation because the soil was already wetted from above average winter precipitation.

For fuel energy measurements, a gasoline powered International Harvester 706 tractor was equipped with remote controlled volumetric fuel measuring cylinders. The cylinders, mounted to the right of the main fuel tank, can be seen in Fig. 3. Fuel and time measurements were made for replicated 400-m passes during all tillage and planting operations in 1982. Fuel use for spraying operations was estimated based on previous tests. Equivalent diesel consumption values were computed from Nebraska Tractor Tests 856 and 858 for IHC 706 diesel and gasoline tractors, respectively (Implement and Tractor Redbook, 1973).

Irrigation water was applied through gated pipe and measured with a propeller meter. Similar flow rates were adjusted to individual furrows. Individually calibrated portable "H" flumes, equipped with water level recorders, were used to measure furrow runoff from two furrows per treatment. Irrigation application times were

*Brand names and models are provided for information only and do not imply special endorsement by USDA.

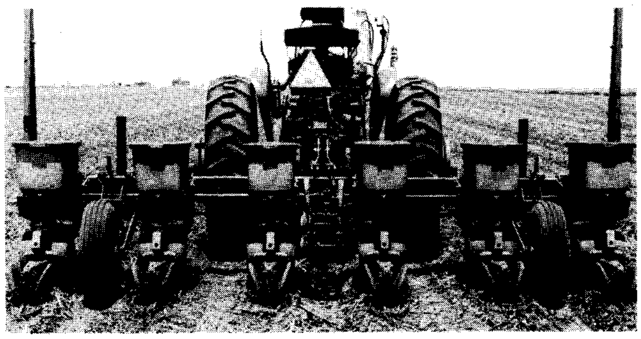

Fig. 3—Double-disk opener planter with front mounted coulters seeding two 0.75-spaced rows on wide beds. Note tractor fuel measurement cylinders visible to the right of the operators seat.

about 30 h at 1.0 L/s (16 gal/min) flowrate per furrow for preplant and about 24 h at 0.76 L/s (12 gal/min) per furrow for seasonal applications. Soil water contents were determined gravimetrically by 0.3-m increments to 1.8 m deep at the beginning of the growing season and after harvest. Seasonal water use was determined from a net water balance of net soil water depletion between planting and harvest, irrigation intake, and seasonal rainfall, assuming negligible deep percolation.

Sorghum was combine harvested on November 23, 1981; October 20, 1982; and November 3, 1983, using a 4-row header described by Allen and Hollingsworth (1981). Samples for grain yield were obtained at three sites (4 rows wide by 30 m long) in each treatment strip.

TABLE 2. TILLAGE DEPTH AND PREPLANT IRRIGATION APPLICATION, RUNOFF, AND INTAKE, BUSHLAND, TEXAS (1981-82)

Tillage treatment		Till depth	Preplant irrigation		
			Applied	Runoff	Intake
		------------- cm -------------			
1981					
T-1	Sweep	12-15	16.6	0.2	16.4
T-2	NT-rip*	30	17.3	1.3	15.9
T-3	NT beds		18.0	1.9	16.1
T-4	Convent.	12-14	15.9	2.8	13.1
1982					
T-1	Sweep	12-15	17.1	1.5	15.6
T-2	NT-rip*	30	16.9	1.7	15.2
T-3	NT beds		14.7	0.6	14.1
T-4	Convent.	18-20	18.8	0.6	18.2

*No-till beds with furrows ripped.

RESULTS AND DISCUSSION

Tillage Operations and Seedbed Preparation

Shredding of stalks in the fall left about 25% soil cover after over-winter decomposition in 1981 and 1982. Stalks were not shredded in 1983 because harvesting traffic had flattened about 50% of the stalks. Soil cover was about 60% before early spring tillage in 1983. Sweep-undercutting 15 to 18 cm deep on T-1 left the surface condition loose and only partially settled after the preplant irrigation in 1981 and 1982. In 1983, a combination tiller (rolling stalk cutters mounted in front of and directly behind 45 cm sweeps) undercut and firmed the T-1 seedbed in one pass. By seeding time in 1983, the soil cover after tillage on T-1 and T-4 was about 40 and 10%, respectively, and the cover on T-2 and T-3 no-till treatments was 50-60%.

The NH_3 application in the no-till plots with narrow points caused only minimal disturbance to the soil surface. The 0.75-m spaced NH_3 points passed through the dry stalks without plugging. Furrow ripping, more than 25 cm deep in the T-2 plots, brought some clods to the surface. Wet soil in the winter of 1982-83 prevented furrow ripping for the final test season. The adjustable furrow opening machine performed very well. Furrows were opened without clods being left on the surface in the path of the planters. Glyphosate successfully controlled all volunteer sorghum plants.

Seeding Operations

Seeding into the tilled seedbeds of T-1 and T-4 was satisfactory with the double-disk opener planter in 1981 and 1982. The loose undercut beds on the T-1 treatment caused tractor steering control to be difficult during planting in 1981 and 1982.

The firm soil surface on no-till treatments (T-2, T-3) required the use of a rolling coulter on the Max-Emerge planter to assist in soil penetration and residue cutting. Planting was directly over the previous crop rows. A shoulder on the original bubble coulters limited soil penetration and they were replaced with sharp-edged flat notched coulters. Coulter down-pressure was adjusted to maximum. The position of the 0.75-m spaced planter row units, in relation to the wide beds and furrows, is shown in Fig. 3.

The staggered double-disk openers on the Early Riser planter, used in 1983, satisfactorily penetrated the firm soil on the no-till treatments. Both planters featured positive seed depth control by use of depth control wheels straddling the double-disk openers. Both planters performed well when properly equipped and adjusted. No residue plugging occurred while planting the 0.75-m spaced rows. There were no noticeable differences in plant stands between tillage treatments.

Tillage Effect on Irrigation Intake

The depth and type of tillage used usually has more effect on irrigation intake during the first application after tillage than during succeeding applications. For this reason, the tillage type, depth, and related preplant irrigation amounts are presented for 1981 and 1982 in Table 2. The treatments with greater intake generally required slightly extended furrow flow times and proportionally larger applications.

Above average summer rainfall after stand establishment in 1981 and 1982 reduced seasonal irrigation requirements. A preplant irrigation was not applied in 1983 because of a wet soil profile from above average winter precipitation. The chiseling operation with conventional tillage (T-4) was deeper in 1982 than other years and the soil water content was conducive to good soil fracturing at that time. This resulted in an increased water intake during the preplant application (Table 2) and continued higher intake during later seasonal irrigation (Table 3). The shallower tillage for T-4 in 1981 resulted in the lowest preplant irrigation intake.

With sweep tillage (T-1), all of the soil above the blade is lifted and loosened, which enhances lateral wetting away from furrows. Furrow ripping to 30 cm deep had a slight effect upon preplant irrigation intake in 1982 and none in 1981, which was less response than was expected. It had been assumed that ripping would fracture the soil and increase intake. The slight effect in 1982 continued through the seasonal irrigations (Table 3). Apparently, loosening by sweeps of the 15-cm deep Ap horizon, that enhances lateral water movement from furrows, is as beneficial to intake as wide-spaced furrow ripping into the dense B21t horizon of the Pullman clay loam.

Irrigation Water Use and Grain Yields

Grain yield and water use data are presented in Table 3. Yield levels in 1981 were relatively low because of the late reseeding date. Only one seasonal irrigation was applied on August 5. That irrigation was followed by a period of precipitation totaling 28 cm during August and September which was 70% above average. The tillage treatments had very little effect on seasonal water use or seasonal water use efficiency (WUE). Grain yields for the undercutting treatment were about 12% lower than the

TABLE 3. GRAIN YIELD; SEASONAL RAINFALL AND RUNOFF; SEASONAL IRRIGATION, RUNOFF, AND INTAKE; AND SEASONAL PROFILE DEPLETION, WATER USE, AND WATER USE EFFICIENCY (1981-83) BUSHLAND, TEXAS

Treatment		Grain yield	Seasonal Rainfall	Rainfall runoff	Irrig.	Irrig. runoff	Irrig. intake	Profile depletion	Water use	Water use eff.
		kg/ha	mm							kg/m^3
1981										
	T-1	4030b*	305	76	107	0	107	101	437	0.92b*
	T-2	4460a		63		4	103	82	427	1.04a
	T-3	4550a		69		4	103	91	430	1.06a
	T-4	4380a		69		3	104	112	452	0.97b
1982										
	T-1	7580a	317	46	331	96	235	14	520	1.45a
	T-2	7240a		51	340	79	261	15	542	1.34b
	T-3	7260a		60	336	96	240	16	513	1.42a
	T-4	7290a		38	338	32	306	10	595	1.22c
1983										
	T-1	4720a	108		477	79	398	56	562	0.84b
	T-2	4685a			449	81	368	32	508	0.92a
	T-3	4650a			449	96	353	38	499	0.93a
	T-4	3955b			477	24	423	20	551	0.72c
Average										
	T-1	5440a	243	41	305	58	247	57	506	1.12a
	T-2	5460a		41	299	55	244	43	492	1.10a
	T-3	5485a		43	297	65	232	48	481	1.14a
	T-4	5210a		35	307	20	282	47	538	0.96b

*Column values for individual years followed by the same letter are not significantly different at the 5% level, according to Duncan's multiple range test.

other treatments in 1981. In 1982, the undercut treatment yields were slightly higher than other treatments.

In 1982, the July through September rainfall was about 20% above average and only three seasonal irrigations were applied. The conventionally tilled (T-4) treatment had considerably less furrow runoff and more intake and seasonal water use than other treatments without any increase in grain yield. The difference in intake was caused by the deeper and more extensive conventional tillage. The seasonal WUE was significantly less for T-4 in 1982. The overall grain yields were higher and more typical in 1982 because of a normal stand establishment date and a full-term frost-free growing season. Accordingly, the seasonal WUE was much higher in 1982 than in 1981 or 1983.

In 1983, the soil profile was fully wetted by over-winter precipitation. However, only about 110 mm of rain was

TABLE 4. AVERAGE TIME, DIESEL* FUEL CONSUMPTION RATES, AND FUEL, LABOR, AND HERBICIDE COSTS TO TILL AND PLANT FURROW IRRIGATED CONTINUOUS GRAIN SORGHUM GROWN ON A FINE TEXTURED SOIL IN THE SOUTHERN HIGH PLAINS USING A 56-kW (75-hp) TRACTOR WITH 6-ROW EQUIPMENT

Operation	Sweep Time, h/ha	Sweep Fuel, L/ha	No-till Rip Time, h/ha	No-till Rip Fuel, L/ha	No-till Time, h/ha	No-till Fuel, L/ha	Disk-Chisel Time, h/ha	Disk-Chisel Fuel, L/ha
Disk X(2)							1.2	6.0
Chisel							0.6	11.7
Shred	0.6	9.3	0.6	9.3	0.6	9.3	0.6	9.3
Chisel NH_3	0.6	10.0	0.6	10.0	0.6	10.0	0.6	10.0
Sweep	0.6	11.6						
Furrow rip (1.5-m furrow space)			0.5	7.5				
Open furrows	0.5	6.5	0.5	6.5	0.5	6.5	0.5	6.5
Cultivate	0.6	9.0					0.6	9.0
Apply propazine†	0.3	1.8	0.3	1.8	0.3	1.8	0.3	1.8
Apply glyphosate†			0.3	1.8	0.3	1.8		
Plant	0.6	3.7	0.6	3.7	0.6	3.7	0.6	3.7
Total	3.8	51.9	3.4	40.6	2.9	33.1	5.0	58.0

Labor and fuel costs	Sweep $/ha	No-till Rip $/ha	No-till $/ha	Disk-Chisel $/ha
Labor‡	20.90	18.70	16.00	27.50
Fuel§	15.55	12.20	10.00	17.40
Propazine‖	14.85	14.85	14.85	14.85
Glyphosate**		22.45	22.45	
Total	51.30	68.20	63.30	59.75

*Gasoline powered IHC 706 tractor was used in study. Equivalent diesel consumption computed from Nebraska Tractor Tests 856 and 858 for IHC 706 diesel and gasoline tractors, respectively (Implement and Tractor Redbook, 1973).
†Values include energy for tractor fuel only.
‡Labor = $5.50/h.
§Fuel = $0.30/L.
‖Propazine = $5.50/kg AI.
**Glyphosate = $66.00/kg AI.

received during the growing season and four irrigations were required. The grain yields were generally low in 1983 because of a record early freeze on September 21, which prematurely terminated grain filling. Thus, seasonal WUE was also correspondingly low. The conventionally tilled treatments yielded less than the other treatments in 1983. Irrigation runoff was much less for T-4 in 1983. Seasonal water use for the tilled treatments (T-1, T-4) was greater than for no-till (T-2, T-3). Thus, no-till treatments had significantly higher seasonal WUE than did sweep or conventional tillage. This response is attributed to greater soil residue cover (about 50%) on no-till plots which reduced early season evaporation and higher irrigation water intake where the surface soil was disturbed by tillage.

Time, Energy, and Cost Efficiency

In Table 4, the time and energy requirements of 6-row equipment and a 56-kW (75-hp) tractor for all operations through tillage, planting, and postemergence herbicide application are presented. Differences in fuel consumption between the tillage treatments varied proportionally with the time required. The time requirements for sweep tillage, no-till beds with ripped furrows, and no-till bed treatments wre 76, 68, and 57%, respectively, of that for conventional tillage. The tractor fuel use was 89, 70, and 57% for the same respective treatments, compared with conventional tillage.

The variable costs for labor, fuel, and herbicides, not including harvesting, are also presented in Table 4. The costs ranged from a high of $68.20/ha for no-till beds with ripped furrows to a low to $51.30/ha for sweep tillage. The no-till bed treatment cost $3.50/ha more than conventional tillage, but that small difference would be more than offset by the increased average grain yield. The lower cost of limited (sweep) tillage plus the advantage of not having to rely on a systemic herbicide to control volunteer sorghum make it the best choice of the tillage methods tested because there was no yield advantage for the higher cost methods.

SUMMARY AND CONCLUSIONS

Irrigated grain sorghum was grown on wide flat beds separated by 1.5-m spaced furrows on the Southern High Plains. Placing plant rows 0.75 m apart on the wide beds permitted wheel traffic to be confined to the centers of the beds rather than in water furrows. The relatively wide plant row and furrow spacing allowed limited tillage and no-till methods to be evaluated without machine plugging by residue. Glyphosate successfully controlled volunteer sorghum in no-till treatments. Furrow ripping 30 cm deep into the dense B2 horizon of the clay loam soil did not significantly increase irrigation water intake on the no-till bed treatment. Irrigation intake was generally proportional to the depth of tillage between the sweep-undercut and conventionally tilled treatments.

Planting into relatively firm soil on no-till beds required sharp rolling coulters with added down pressure on a conventional double-disk opener planter to assist in penetration and to place seed at a sufficient depth. A staggered double-disk opener planter, used in the third year, successfully cut through residue and penetrated the firm soil for seed placement when the down pressure was properly adjusted.

There was no significant grain yield response to tillage, although conventional tillage yielded about 5% less than other treatments. Average seasonal water use efficiencies were about equal for all tillage treatments except for conventionally tilled, which averaged significantly less (14%) than others.

Fuel energy and time requirements were reduced with limited and no-tillage although no-till costs were higher. The limited (sweep) tillage treatment had the lowest variable costs $51.30/ha which was $17.00, $12,00, and $8.50/ha lower than were no-till beds with furrow ripping, no-till beds, and conventional tillage, respectively. In addition to being most cost effective, the sweep treatment eliminated the risk of complete dependence upon chemical control of volunteer sorghum as was required with no-till.

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